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Contribution of dieting to the inverse association between energy intake and body mass index

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Objective: To examine the association of energy and % energy from fat with body mass index (BMI) and determine if self-reported dieting altered observed associations.
Design: Dietary intake data based on dietary recalls from four nonconsecutive days over a 1 year period were examined relative to BMI. The relation between energy intake and % energy from fat and BMI was examined by linear regression analysis.
Subjects: The sample included 1854 free-living women aged 19–50 years who participated in the 1985–6 Continuing Surveys of Food Intakes by Individuals conducted by the United States Department of Agriculture.
Results: Reported energy intake was inversely associated with BMI (regression coefficient (β) = −0.001 24, standard error (s.e.) = 0.000 31). Controlling for low energy dieting alone reduced the inverse energy intake–BMI association by approximately 20% (β = −0.001 00, s.e. = 0.000 31), compared to reductions of 16%, 13% and 10%, respectively, when health status, age and education were added individually to the energy intake – BMI linear regression. Physical activity, smoking status, % energy from fat and report of low fat dieting did not reduce the energy intake – BMI association. Controlling for nondietary factors related to BMI and potentially influencing energy intake reduced the inverse energy intake – BMI association by ~22% (β = −0.000 97, s.e. = 0.000 25). Further adjustment for low energy dieting on day 1 reduced the inverse energy intake – BMI association by 40% (β = −0.000 74, s.e. = 0.000 26), suggesting that intermittent energy restriction was a significant factor in the reduced energy intake reported among overweight women. Percent energy from fat was not associated with BMI (β = 0.049, s.e. = 0.025, P = 0.055). Exclusion of 37 women reporting poor health status further attenuated the inverse association between energy intake and BMI (β = −0.000 64, s.e. = 0.000 26), while it strengthened the previously non-significant positive association between % energy from fat and BMI (β = 0.062; s.e. = 0.024).
Conclusion: Intermittent energy restriction appeared to be a significant factor in the reduced energy intake reported among overweight women in this sample. Adequate assessment of energy expenditure is required to correctly interpret the association of energy intake to body weight.
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Descriptors: body weight, dieting, energy, fat, obesity, physical activity

Introduction

Positive energy balance, defined as energy intake in excess of expenditure, is required for the development of excess body weight. In keeping with this definition, it is commonly perceived that overweight individuals must consume more energy than normal or underweight individuals. However, research on the relationship of energy intake to overweight is inconsistent. Although several studies have reported positive (Matter *et al*, 1980; Colditz *et al*, 1990; Tucker & Kano, 1992) or no associations (Edholm *et al*, 1955; Myers *et al*, 1988; Dreon *et al*, 1988) between energy intake and body weight, most studies have reported negative associations (Thomson & Billewicz, 1961; Stefanik *et al*, 1959; Maxfield & Konishi, 1966; McCarthy, 1966; Baecke *et al*, 1983; Kromhout, 1983; Braitman *et al*, 1985; Romieu *et al*, 1988; Hulten *et al*, 1990; Mertz *et al*, 1991; Croft *et al*, 1992). Population-based surveys suggest that overweight individuals consume, on average, less energy than normal or underweight individuals (McCarthy 1966, Kromhout 1983, Braitman *et al*, 1985; Romieu *et al*, 1988; Croft *et al*, 1992).

Four explanations for these findings have been proposed. One interpretation of these finding, recently strengthened by research using doubly-labeled water to assess energy expenditure in the free-living state, is that overweight individuals under-report food intake to a greater extent than normal or underweight individuals (Goldberg *et al*, 1991; Black *et al*, 1991). However, other recent reports have not found evidence of under-

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reporting among overweight compared to lower weight individuals (Klesges *et al*, 1988; Myers *et al*, 1988).

Another interpretation of the inverse association between energy intake and body weight is that overweight individuals are less active (Mayer *et al*, 1956; Ravussin *et al*, 1988; Ravussin & Bogardus, 1989; George *et al*, 1989; Miller *et al*, 1990; Clark *et al*, 1992; Voorips *et al*, 1992), a hypothesis that is consistent with findings from several population-based surveys (Seidell *et al*, 1991; Zimet *et al*, 1991; Williamson *et al*, 1993). Furthermore, physical activity is considered to be one of the most variable components of total energy expenditure in the free-living state (Ravussin & Swinburn, 1993). Analyses of the association between energy intake and body weight in population-based studies generally have not included adjustment for energy expenditure due to physical activity.

A third interpretation is that overweight individuals are more likely to be dieting or restricting food intake at any one point in time than are individuals who are not overweight (DHHS publication, 1988). Energy intake estimates based on a single 24-h dietary recall, used in some population-based analyses of the association between energy intake and weight, have been criticized. Studies that assess energy intake at a single point in time or over a very short time interval may capture intake during a period of energy restriction or excess that may not reflect energy intake over a longer interval. If overweight individuals are more likely to be dieting at any one point in time, then a single 24-h recall is more likely to capture episodes of energy restriction among overweight individuals compared to normal and underweight individuals.

Finally, dietary fat intake may also influence body weight. Recent findings of weight loss in dietary interventions focusing on reducing fat rather than energy have generated renewed interest in the impact of dietary fat intake on body weight (Sheppard *et al*, 1991; Kendall *et al*, 1991). Several studies have demonstrated that two behaviors associated with long-term maintenance of weight loss among overweight individuals are adoption of low fat eating patterns and physically active lifestyles (Dreon *et al*, 1988; King *et al*, 1989). Studies have suggested that fat is more efficiently metabolized and stored compared to carbohydrate (Schwartz *et al*, 1985; Schutz & Jequier, 1989). In addition, in controlled diet studies of fat restriction, energy intakes were lower during consumption of low fat compared to high fat diets (Lissner *et al*, 1987; Tremblay *et al*, 1989; Kendall *et al*, 1991; Lawton *et al*, 1993). Conversely, other studies find either no association or a lack of an association independent of energy intake between dietary fat intake and body weight or weight gain (Leibel *et al*, 1992; Kant *et al*, 1995). These latter studies may be limited by small numbers of participants or by dietary intake data based on a single 24-h period.

The 1985 and 1986 Continuing Surveys of Food Intake by Individuals (CSFII 85–86) provide an opportunity to examine data pertinent to each of these interpretations of energy intake and relative weight. CSFII data on the same individuals were collected on over a year-long interval. Because these surveys contain multiple nonconsecutive days of dietary recalls, the possible influence of dieting estimated from self-reports of dieting at the time of the first interview can be examined.

Subjects and methods

Sampling and study procedures

Data from the United States Department of Agriculture's (USDA) CSFII 85–86 were used. The design provided two multistage stratified area probability samples of women aged 19–50 and their children aged 1–5 years, representative of the 48 coterminous states.

Survey participants were asked to provide dietary data via six nonconsecutive 1-day dietary recalls collected by telephone at approximately 2-month intervals throughout the year. Interviews occurred from April 1985 through March 1987. Eligible households were scheduled for interviews on different days of the week to provide representativeness of dietary intake data over all days of the week. The first interview was conducted in person; subsequent interviews were conducted by telephone. Each respondent was asked to recall the kinds and amounts of foods and beverages consumed at home and away during the previous day.

While the design of the surveys called for collection of 6 nonconsecutive days of information, less than half of the respondents interviewed initially completed the full 6 days of report. Consequently, USDA constructed a sample of all women who had completed any 4 of the possible 6 days of report, 71% of the initial CSFII 85 sample of women, and 76% of the initial CSFII 86 sample of women. For all selected women, the first day of information was included. For those women who reported 5 or 6 days of information, USDA randomly selected the 3 additional days included. This dataset, used in these analyses, is composed of 2134 women, each with 4 days of dietary information. More complete descriptions of the sampling and study procedures are found in CSFII reports 85–4 and 86–3 (CSFII Report No. 85–4, 1987; CSFII Report No. 86–3, 1988).

Analytic cohort

From the initial sample of 2134 women, 228 women were excluded from the analysis because they were pregnant or lactating at some time during the survey, 39 were excluded because they reported being ill for two or more of the 4 days of reporting, and 13 because they were missing height or weight data. The final analytic cohort included 1854 women. Individual days of data for these remaining women were excluded for atypical intake due to illness on the day of reporting (297 days).

Definition of relative weight categories

Weight and height were self-reported at the first interview. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. The population-based descriptive cutpoints for three categories of relative weight status developed by the National Center for Health Statistics were used for this analysis (Abraham *et al*, 1983). Underweight was defined as a BMI of 19.1 kg/m^2 or less, equivalent to the 15th percentile of BMI for 20–29-year-old US women as estimated in the second National Health and Nutrition Examination Survey. Overweight was defined as a BMI of 27.3 kg/m^2 or more, equivalent to the 85th percentile of BMI for 20–29-year-old women. This definition of overweight is similar to a body weight 20% above the 'ideal body weight' a defined in the 1983 Metropolitan Life Tables of Recommended Weights.

Normal weight was defined as a BMI between 19.1 and 27.3 kg/m^2.

Definition of independent variables
Self-report of currently being on a special diet was collected on the first day of reporting. Reports of two types of diets, energy restriction/weight loss and low fat/cholesterol, were included as independent variables in this analysis. Two descriptors of energy intake (mean and $\leq$4.19 MJ [1000 kcal] on any day) and mean % energy from fat intake were examined. Mean % energy from fat was calculated for each woman by summing each woman's intake of fat in grams over the available days, multiplying by the number of MJ of energy per gram of fat, and dividing by the sum of the energy intake over the available days. In addition, in order to examine the theoretical likelihood of under-reporting of energy intake by relative weight categories, a cutpoint for minimum estimated energy intake for each woman was determined based on estimates of basal metabolic rate (BMR) derived from equations utilizing weight, height and age (Schofield *et al*, 1985). As suggested by Black *et al* (1991) for assessment of individuals with 4 days of dietary records, individuals with a reported mean energy intake (EI) to BMR ratio of less than 1.06 were considered to be 'under-reporters'.

Data on other independent variables – age, educational level, health status, smoking status, and job/home-related and leisure-time physical activity – were assessed by questionnaire, also on the first day of reporting. The categories for these covariates and their distributions by relative weight categories are shown in Table 1.

Statistical analysis
The percentages of persons with intakes of 4.19 MJ (1000 kcal) or less, an energy intake commonly used in energy restriction diets, and the prevalence of reported dieting, either energy restriction/weight loss or low fat/cholesterol, and of under-reporting were examined by relative weight categories. Differences in mean values and percent distributions of variables shown in Table 2 were examined among relative weight categories and among three age groups (19–29, 30–39, 40–50). F-tests showed no differences in these values among age groups; therefore, only the values for relative weight categories are shown.

The association between potential weight-related factors and body weight was examined in simple linear regressions with potential weight-related factors entered individually as independent variables. Job-related physical activity was not associated with BMI as shown in Table 1 and was therefore not included in subsequent regression models.

The following approach was used to assess the association between energy intake and BMI. First, each potential weight-related confounder was entered individually with energy intake in a linear regression model with BMI as the dependent variable (Table 4). Second, in order to assess the association between energy intake and BMI controlling for available factors reported to influence body weight, a multiple linear regression model was run with energy intake, % energy from fat, age, educational status (<12, 12, >12 years), leisure-time physical activity (light, moderate, heavy), smoking (never, former, current), and health status (excellent, very good, good, fair, poor) entered as independent variables (model A, Table 4). Then, a categorical variable based on the history of energy restriction/weight loss dieting was added to this model in order to assess if dieting further altered the association between energy intake and BMI (model B, Table 4 and model, Table 5). Finally, in order to assess if low fat dieting altered the association between energy intake or between % energy from fat and BMI, a categorical variable based on low fat/cholesterol dieting on day 1 was added to model A (model C, Table 4).

The variables for extreme intake and under-reporting were also considered for addition to the model, but Spearman correlations indicated that they were highly correlated to mean energy intake. Due to the high correlations between energy intake and the two measures of extreme intake and under-reporting ($r = -0.78$, 0.49 and -0.82; $P = 0.0001$, for $\leq$4.19 MJ [1000 kcal], $\geq$12.56 MJ [3000 kcal], and under-reporting, respectively) the variables for extreme intake and under-reporting were not entered in the multiple regression models examining the association between energy intake and BMI. The correlations were low between the other major dietary variables entered in the multiple models. For example, the correlation between energy and % energy from fat was 0.15, $P = 0.0001$; for energy and history of low energy dieting it was -0.16, $P = 0.0001$; and for % energy from fat and history of low fat dieting it was -0.05, $P = 0.001$.

Weighting factors that adjust for differential probability of selection and household and individual non-response were incorporated in all analyses. The descriptive analyses were run in SAS; the regression analyses were run using SUDAAN, a software package appropriate for analysis of surveys with complex sample designs (Shah, 1993).

Results

The mean weight, height and BMI for the sample was 64.9 kg, 1.63 m and 24.4 kg/m^2, respectively. The mean weight increased across the three relative weight groups: 47.9, 60.0 and 84.7 kg for under-, normal- and overweight women respectively. Similarly the mean BMI increased across the three relative weight groups: 18.0, 22.5 and 32.1 kg/m^2, respectively. Mean height was 1.63 m for each of the three relative weight groups.

The distribution of the cohort by relative weight categories and mean values for BMI by subgroups of age, educational status, physical activity, smoking status and health status are shown in Table 1. The prevalence of overweight increased with age while the prevalence of underweight decreased with age. Women aged 40–50 were heavier (mean BMI of 25.6 kg/m^2) compared to younger women (BMIs of 24.6 and 22.9 kg/m^2 for women aged 30–39 and 19–29, respectively). The higher BMIs among older women were due to higher weights rather than lower heights. Mean height was virtually identical across all age groups (data not shown). The prevalence of overweight was higher among women with less education, low levels of leisure-time physical activity, former and never smokers, and women reporting fair or poor health status. The prevalence of underweight was higher among less educated women, current smokers and women reporting poor health status.

Table 1 Distribution of women by weight-related factors and relative weight categories and mean BMI by these subgroups among sample of 1854 women

Weight-related variables	*n*	*Relative weight status (%)* Under (149/8.0%)	Normal (1265/68.2%)	Over (440/23.7%)	*BMI*[a] *Mean ± s.e.m.*[a]
Age (years)[b]					
19–29	538	13.1	72.7	14.3	22.9 ± 0.2
30–39	717	7.4	68.3	24.3	24.6 ± 0.2
40–50	599	4.3	64.1	31.6	25.6 ± 0.2
Education (years)[b]					
< 12	282	11.2	59.9	29.1	24.9 ± 0.4
12	787	6.1	67.0	26.9	24.9 ± 0.2
> 12	779	9.0	72.4	18.6	23.8 ± 0.2
Job home Activity					
light	473	8.3	66.0	25.8	24.7 ± 0.3
moderate	1034	7.6	69.1	23.3	24.3 ± 0.2
heavy	339	8.6	69.3	22.1	24.3 ± 0.3
Leisure activity[b]					
light	716	7.1	62.2	30.7	25.3 ± 0.2
moderate	948	8.5	70.7	20.8	24.0 ± 0.2
heavy	181	8.3	80.1	11.6	23.1 ± 0.3
Smoking					
current	594	10.3	69.0	20.7	23.9 ± 0.2
former	259	5.8	66.4	27.8	25.0 ± 0.4
never	992	7.4	68.3	24.4	24.6 ± 0.2
Health status[b]					
excellent	693	7.9	76.3	15.7	23.5 ± 0.2
very good	589	7.8	69.4	22.8	24.2 ± 0.2
good	397	8.1	59.7	32.2	25.5 ± 0.3
fair	135	8.9	53.3	37.8	25.8 ± 0.5
poor	37	10.8	43.2	46.0	28.1 ± 1.6

Numbers of women by individual variables may not sum to 1854 due to missing values.
[a] BMI (body mass index, kg m^2).
[b] Mean BMIs significantly different among covariate categories by *F*-test; $P < 0.001$.

Mean energy intake over the four days of data collection was lowest among overweight women, 5.94 MJ (1420 kcal), and highest among underweight women, 7.03 MJ (1680 kcal), as shown in Table 2. Similarly, overweight women were most likely to report consuming less than 4.19 MJ (1000 kcal) on any day of data collection (60%), while underweight women were least likely to report consuming such low energy intakes (41%). Similarly, energy restriction/weight loss dieting on day 1 was reported more frequently among overweight women (15%), compared to normal and underweight women (7% and 3%, respectively). There was no significant difference in the % energy from fat, or the prevalence of report of low fat/cholesterol dieting on day 1 by relative weight status.

The prevalence of under-reporting by the measure of EI/BMR of <1.06 suggested by Black *et al* was high (Table 2), increased across relative weight categories, and ranged from 29% among underweight women to 71% among overweight women. In addition, as shown in Table 3, the prevalence of under-reporting declined with increasing years of education and increases in leisure time physical activity, and was lower among nonsmokers and people with better health status. However, tests for linear trend for these changes were significant only for education and health status. The

Table 2 Measures of body mass index (BMI), basal metabolic rate (BMR), energy intake (EI) and % energy from fat intake and history of dieting by relative weight categories among sample of 1854 women

Weight and dietary intake variables	*Relative weight status* Under (149/8.0%)	Normal (1265/68.2%)	Over (440/23.7%)
BMI (kg/m^2)[ab]	18.0 ± 0.07	22.5 ± 0.06	32.1 ± 0.22
BMR$_{est}$ (MJ)[ab]	5.1 ± 0.42	5.6 ± 0.16	6.6 ± 0.31
Energy intake (EI) measures			
Reported EI (MJ)[ab]	7.03 ± 0.20	6.32 ± 0.06	5.94 ± 0.09
≤4.19 MJ (1000 kcal) (%)[b]	41.2	50.2	60.0
Low energy dieting (%)[b]	3.0	7.2	15.4
EI < 1.06 × BMR (%)[b]	28.9	47.9	71.1
% energy from fat intake	36.7 ± 0.6	36.8 ± 0.2	36.9 ± 0.3
Low fat dieting (%)	2.0	2.3	4.2

[a] Mean ± s.e.m.
[b] Values significantly different by weight groups by *F*-test; $P < 0.001$.

Table 3 Prevalence of under-reporting (EI < 1.06 × BMR) stratified by weight-related factors

Weight-related variables	*n*	*Percent with EI < 1.06 × BMR*
Age (years)		
19–29	538	53.0
30–39	717	48.8
40–50	599	54.6
Education[a]		
<12	282	60.0
12	787	55.2
>12	779	45.3
Leisure activity		
Light	716	54.1
moderate	948	51.2
heavy	181	47.5
Smoking		
current	594	54.4
former	259	49.0
never	992	51.2
Health status[a]		
excellent	693	47.5
very good	589	50.8
good	397	55.4
fair	135	64.4
poor	37	70.3

Numbers of women by individual variables may not sum to 1854 due to missing values.
[a] Test for linear trend significant; $P < 0.001$.

Table 4 Beta coefficients and standard errors (s.e.) for mean energy intake computed from linear regression models for body mass index (BMI, kg/m^2)

Models[a]	*Beta ± s.e.*	*F-test*[b]
Mean energy	−0.001 24 ± 0.000 31	16.34
+ % energy fat	−0.001 31 ± 0.000 29	20.28
+ low energy dieting	−0.001 00 ± 0.000 31	10.69
+ low fat dieting	−0.001 23 ± 0.000 31	16.27
+ age	−0.001 08 ± 0.000 28	14.60
+ educational status[c]	−0.001 11 ± 0.000 29	14.45
+ physical activity[c]	−0.001 25 ± 0.000 30	17.01
+ smoking status[c]	−0.001 26 ± 0.000 31	17.11
+ health status[c]	−0.001 04 ± 0.000 28	13.32
Model A[c]	−0.000 97 ± 0.000 25	14.72
Model B[c]	−0.000 74 ± 0.000 26	8.05
Model C[c]	−0.000 97 ± 0.000 26	14.46

[a] Models: Model A contains mean energy intake, mean % energy fat, age, educational level (<12, 12, >12 years), smoking (never, former, current), physical activity leisure (light, moderate, heavy), and health status (excellent, very good, good, fair, poor) as independent variables. Model B contains variables in model A plus report of low energy dieting (yes, no). Model C contains variables in model A plus report of low fat dieting (yes, no).
[b] $P < 0.001$ for all F-tests shown.
[c] n for these models less than 1854 due to missing values. n for models A, B and C is 1831.

greatest differences in prevalence of under-reporting were observed according to health status: under-reporting increased with declines in reported health status, such that 48% of women with excellent health status and 70% of women with poor health status were considered to be under-reporting.

In simple regression analyses, all of the dietary variables except % energy from fat were significantly correlated with BMI (data not shown). Of the nondietary covariates, only job/home-related physical activity was not correlated with BMI. Leisure-time physical activity was correlated with BMI.

Mean energy intake was significantly and inversely correlated with BMI in multiple regression analysis as demonstrated by the regression coefficients shown in Table 4. Addition of low energy dieting, age, education and health status individually to the energy–BMI regression model reduced the negative β coefficient for energy intake. The largest reduction was found with adjustment for low energy dieting (β for energy intake $= -0.001\,00$, $P = 10.69$). Adjustment for all available weight-related confounders in the predictor model for BMI (model A) reduced the β coefficient for energy intake from $-0.001\,24$ to $-0.000\,97$. Addition of low energy dieting (model B) further reduced the β coefficient for energy intake to $-0.000\,74$. Addition of low fat/cholesterol dieting (model C) did not alter the β coefficient for energy intake from the initial adjusted model (model A).

Unlike the relationship between energy intake and BMI, the correlation between mean % energy from fat and BMI increased in size and strength with the adjustment for potential confounders shown in model B. For example, the β coefficient in the adjusted model for mean % energy from fat was 0.049, $P = 0.06$ (Table 5), compared to a β coefficient in the unadjusted model of 0.0225, $P = 0.40$ (data not shown).

The predictor model in Table 5 demonstrates that, with the exception of % energy from fat, all of the other factors examined were associated with BMI. It is of note that leisure-time physical activity remained strongly associated with BMI in the adjusted model, despite the

Table 5 Predictor model for determination of body mass index derived from multiple linear regression analysis[a] among sample of 1831 women

Variables[b]	*Beta ± s.e.*	*F-test*	*P*
Mean energy	−0.000 74 ± 0.000 26	8.05	0.0000
Mean % energy fat	0.049 ± 0.025	3.84	0.0545
Low energy dieting	2.66 ± 0.39	45.27	0.0000
Age	0.106 ± 0.016	43.59	0.0000
Educational status	−0.156 ± 0.057	7.50	0.0082
Physical activity	−0.828 ± 0.213	15.12	0.0003
Smoking status	−0.591 ± 0.193	9.37	0.0034
Health status	0.704 ± 0.164	18.38	0.0001
Intercept: 19.447			

[a] Test of the model: $F = 29.08$; $P < 0.000\,01$.
[b] Variables entered as indicated: mean energy intake, mean % energy fat, and age as continuous; educational status (<12, 12, >12 years), physical activity leisure (light, moderate, heavy), smoking status (never, former, current), and health status (excellent, very good, good, fair, poor), and report of low energy dieting (yes, no). n is less than 1854 due to missing values.

admittedly crude measure of physical activity available. Removal of physical activity from the model in Table 5 attenuated the inverse association between energy intake and BMI slightly ($\beta = -0.000\,70$, $P = 0.009$).

Discussion

Energy intake

The inverse association between energy and relative weight among women in the 1985–1986 CSFII is consistent with reports from other population-based studies (McCarthy, 1966; Kromhout, 1983; Braitman *et al*, 1985; Romieu *et al*, 1988; Croft *et al*, 1992). Overweight women were less active, as previously reported in other surveys (Seidell *et al*, 1991; Zimet *et al*, 1991; Williamson *et al*, 1993). Moreover, overweight women were more likely to be dieting at baseline, and eating less than 4.2 MJ (1000 kcal) on any one of the 4 days of data collection than were women who were not overweight, not previously described in published reports. Controlling for low energy dieting alone reduced the inverse energy intake–BMI association by ~20%, compared to reductions of 16%, 13% and 10%, respectively, when health status, age and education were added individually to the energy–BMI linear regression. Physical activity, smoking status, % energy from fat, and report of low fat dieting did not reduce the energy intake–BMI association. Controlling for nondietary factors related to BMI and potentially influencing energy intake reduced the inverse energy intake–BMI association by ~22%. Further adjustment for low energy dieting on day 1 reduced the inverse energy intake–BMI association by 40%, suggesting that intermittent energy restriction was a significant factor in the reduced energy intake reported among overweight women. However, even after adjusting for dieting and the available nondietary factors known to influence body weight (age, educational status, physical activity, smoking and health status), energy intake remained significantly and inversely associated with body mass index. If the extent of misreporting of energy intake does not vary according to body size, these findings would suggest that free-living overweight women consume less energy regardless of their dieting behavior compared to normal and underweight women. However, it is also possible that, if reports of dieting were available for the other 3 days of intake, adjustment for dieting at the time of reported intake would further reduce the inverse association between energy intake and BMI in these data. Reports of dieting may also represent under-reporting in the case where energy restriction dieting is unsuccessful and the reported energy intake reflects dietary goals rather than true energy intake. The inverse association between leisure-time physical activity and BMI suggests that differences in energy expenditure between overweight women compared to women with lower relative weight status may be a contributor to the development and maintenance of overweight among young and middle-aged US women (Mayer *et al*, 1956; Ravussin *et al*, 1988; Ravussin & Bogardus, 1989; George *et al*, 1989; Miller *et al*, 1990; Seidell *et al*, 1991; Zimet *et al*, 1991; Clark *et al*, 1992; Voorips *et al*, 1992; Williamson *et al*, 1993).

The inverse energy intake–BMI association observed in this and other population-based surveys appears to be refuted by reports of a positive association between directly measured sedentary 24-h energy expenditure and body weight (Ravussin & Swinburn, 1993). Based on these reports it is commonly stated that heavier individuals consume more energy than leaner individuals. However, the controlled conditions and confined settings in which energy expenditure is measured directly (as in a respiratory chamber) limit extrapolation to free-living populations. Even within the physically restrictive environment of a respiratory chamber, large differences in 24-h energy expenditure of 0.42–3.4 MJ/day (100–800 kcal/day) have been attributed to differences in spontaneous physical activity (Ravussin *et al*, 1986). In free-living conditions voluntary physical activity is higher (Seale *et al*, 1990) and is thought to vary much more widely (Ravussin & Swinburn, 1993). Furthermore, lower levels of voluntary physical activity have been reported among the overweight from a number of surveys (Seidell *et al*, 1991; Zimet *et al*, 1991; Williamson *et al*, 1993). These findings suggest that a positive association between 24-h energy expenditure and body weight may not be found in free-living populations, particularly in populations where an inverse association exists between voluntary physical activity and BMI.

However, due to recent studies using doubly-labeled water, the most commonly accepted interpretation of the inverse association between energy intake and body weight is that it is a spurious finding due to under-reporting of food intake among overweight individuals compared to normal and underweight individuals (Goldberg *et al*, 1991; Black *et al*, 1991; Lichtman *et al*, 1992; Heitmann, 1993). Using the EI/BMR cutpoints suggested as criteria for under-reporting (Goldberg *et al*, 1991; Black *et al*, 1991), it appears that under-reporting is common in the CSFII data and that it increases with increasing BMI. However, it is important to note that the equations used to estimate BMR are derived from analyses involving generally healthy individuals. Furthermore, these equations are based solely on age, height and weight, which are major but not the only determinants of BMR. In large samples of free-living individuals, it is likely that variability in other factors, such as health status, may contribute to the variability in BMR. Similarly, the commonly suggested inflation factor of 1.5–1.7 across all individuals does not allow for variability in total energy expenditure (TEE) due to differences in physical activity, health status or other factors that might influence the voluntary energy expenditure component of TEE. The wide range of 1.15–2.35 for the TEE/BMR ratio among women calculated based on published data on energy expenditure derived from doubly-labeled water (Schulz & Schoeller, 1994) further suggests that the narrow range being recommended to define under-reporting in large samples may result in incorrect classification of individuals in terms of under-reporting of energy intake.

An alternative measure of dietary intake that might be associated with BMI is variability in energy or fat intake. Because of data indicating that measures of variability, such as standard deviation (s.d.) or coefficient of variation (c.v.), are unreliable when based on a few days of data (Tarasuk & Beaton, 1992), neither of these measures were a focus of this analysis. However, the β coefficient for mean energy intake was attenuated slightly when c.v. for energy was entered in the model shown in Table 5 ($\beta = -0.000\,64$, s.e. $= 0.000\,280$).

Dietary fat

Unlike a number of intervention and clinical metabolic studies that suggest that dietary fat may be correlated with body weight independently of energy intake (Schwartz *et al*, 1985; Dreon *et al*, 1988; King *et al*, 1989; Miller *et al*, 1990; Sheppard *et al*, 1991; Kendall *et al*, 1991), dietary fat was not significantly associated with BMI in this survey. This is consistent with a report of a lack of association between dietary fat and weight change from a prospective population-based survey (Kant *et al*, 1995). It is possible that an association was not observed because BMI may not be a sufficiently sensitive measure of adiposity. In a study which examined differences in various measures of body size and fat mass by levels of % energy from fat, body weight did not vary while measures of truncal subcutaneous fat did vary significantly by level of % energy from fat (Tremblay *et al.*, 1989). It is also possible that an association was not observed because too few women were consuming low fat diets. Generally dietary fat intakes are <20–25% energy from fat in interventions which indicate that decreases in dietary fat intake may improve weight loss and the maintenance of weight loss (Miller *et al*, 1990; Kendall *et al*, 1991). Only 5% of women for the current analysis reported dietary fat intakes of 20% or less. Given known measurement error, especially at low levels of nutrient intake, the actual percent of women in the sample consuming such low levels of fat may be much smaller (Beaton *et al*, 1979).

It is also possible that a small groups of outliers had a large effect on the observed associations. Excluding the 37 women reporting poor health status from the regression model presented in Table 5 modified the β coefficients for both energy and % energy from fat. The inverse association between energy and BMI declined ($\beta = -0.0064$, s.e. $= 0.000\,26$, $P = 0.014$), while the association between % energy from fat and BMI remained positive and became significantly associated with BMI ($\beta = 0.062$; s.e. $= 0.024$; $P = 0.012$). This suggests that differences in dietary intakes among women with differing self-reported health status influenced the observed association between energy, % energy from fat, and BMI.

Under-reporting

'Under-reporting' was more common among women with less education, who were less active, smoked, or had poorer self-reported health status. Therefore, excluding individuals based on the defined criteria for under-reporting would introduce bias into the sample due to differential exclusion of individuals in terms of a variety of other factors related to body weight. In addition, some groups, such as individuals with poor health status, and less activity, who had a high prevalence of under-reporting, are also groups who are commonly perceived to consume fewer calories. It is possible that the lower energy intakes reported in these groups reflect true intakes, and that at least some individuals in these groups are incorrectly classified as 'under-reporters'.

Other methods have been used to attempt to adjust for unreliable measures of exposure, such as excluding 'under-reporters' from analyses or generating imputed energy intake values for individuals who are considered to be 'under-reporters' and using these imputed values in place of the reported energy intake data. Because the variable used to define under-reporting includes BMR estimates based on weight and height (the same measures used to calculate BMI), deletion of 'under-reporters' removes more individuals with low energy intakes as BMI increases and, therefore, eliminates individuals from the regression with large residuals in the low energy intake range. Doing this will usually result in attenuation of the energy/BMI association. Furthermore, this approach still does not correct for possible misreporting in the remainder of the sample. Finally, one might generate imputed energy values for 'under-reporters' from doubly-labeled water studies by entering BMI in regression equations, essentially using the dependent variable, BMI, to derive values for an independent variable, energy intake. In this case, when energy intake (a function of BMI) is placed in a regression model with BMI as a dependent variable, BMI functions as both a dependent and independent variable for those individuals. Given the high proportion of 'under-reporters defined by the criteria of Black & Goldbert, interpretation of the β coefficient for energy intake becomes problematic. Clearly, some method to account for potential under-reporting is desirable in order to correctly interpret analyses of associations between energy intake and health outcomes. However, it is particularly problematic to use measures of under-reporting that are derived from body weight in analyses of the association between energy intake and body weight. Ideally, a measure of under-reporting that is not derived from body weight would be preferable for most analyses of energy intake and health outcomes, as most health outcomes associated with energy intake are also associated with body weight.

Although this dataset has a number of strengths for examining the association between energy and body weight at a population level there are a number of potential weaknesses. The assessment of energy intake is from self-report of dietary intake. Although the majority of studies examining the association between energy intake and body weight or fatness have found negative associations (Thomson & Billewicz, 1961; Stefanik *et al*, 1959; Maxfield & Konishi, 1966; McCarthy, 1966; Baecke *et al*, 1983; Kromhout, 1983; Braitman *et al*, 1985; Romieu *et al*, 1988; Hulten *et al*, 1990; Mertz *et al*, 1991; Croft *et al*, 1992), these have also relied on self-report of dietary intake. A recent survey showing an association between under-reporting of dietary protein intake and body fatness when comparing dietary recall with urinary nitrogen emphasizes the need for less subjective measures of dietary intake (Heitmann, 1993). Urinary nitrogen estimates may be less subjective. However, such biologic measures may be differentially influenced by health conditions that are associated with both body weight and urinary nitrogen excretion, such as hypertension, and therefore may not always be accurate estimates of dietary intake.

The findings from this study are only generalizable to young and middle-aged US women. However, given that the majority of weight loss research and expenditures on weight loss in the US have been directed to this group, data relevant to this group are particularly pertinent (Silberner, 1992). Several factors known to influence body weight in this population are not available in this dataset, such as number of pregnancies prior to the survey. However, a number of other factors known to influence body weight were available, such as physical activity, education, and health status. Another potential weakness was the reliance on self-reported weight. However, high correlations of 0.98 have been reported between current measured and reported weight, with some evidence of minor degrees of over- and underestimation of weight among low and high weight groups, respectively (Stevens *et al*, 1990). In general this type of measurement error for reported weight is likely to result in attenuation in observed associations. Finally, due to the cross-sectional nature of this data set in terms of analyses related to body weight, findings related to energy, fat and body weight must be interpreted cautiously in terms of understanding the role of energy intake in the etiology of overweight.

Conclusion

In summary, in US women aged 19–50 years, reported energy intake was inversely associated with BMI. The magnitude of this inverse association was greatly reduced after controlling for a report of energy restriction dieting on day 1 and nondietary factors related to BMI. These findings indicate that while intermittent energy restriction was an important factor in the reduced energy intake reported among overweight women in this sample, overweight women report consuming less energy regardless of their dieting behavior. Although under-reporting cannot be assessed directly in this data, use of cutpoints of EI/BMR suggested by Black & Goldberg (1991) identifies a high prevalence of 'under-reporting' that increases with BMI. However, the narrow range suggested for these cutpoint criteria do not allow for sufficient variability in physical activity, and do not include adjustment for factors, such as smoking or health status, that may modify BMR in large population samples. These limitations may lessen its utility for defining under-reporting in analyses involving large samples of free-living populations. Leisure-time physical activity was inversely associated with body weight in this sample. These findings reinforce the concept that adequate assessment of energy expenditure is required in order to correctly interpret the association of energy intake to body weight. Measurement of energy expenditure by chamber calorimetry and doubly-labeled water are currently the most precise methods for estimation of energy expenditure. However, the former method restricts voluntary physical activity typical of the free-living state (Seale *et al*, 1990; Ravussin & Swinburn, 1993) and the latter method is currently too expensive to use in large-scale population surveys. At a minimum more complete measures of self-reported physical activity should be included in large-scale population studies that include self-reported dietary intake. This more complete data on physical activity could then be utilized in examining associations between energy intake and BMI and in developing more accurate cutpoints for defining under-reporting.

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